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Ontology Mapping for Enhanced Interoperability of S-100 Geographic Information Registers

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Abstract

In the maritime field, integration of information service architectures and a common data model currently are topics of considerable interest. The International Hydrographic Organization (IHO) introduced the S-100 standard for the universal hydrographic data model and publishes Geographic Information (GI) registers in order to support the wider use of, the ease of access to, and the development of S-100 based product specifications. GI registers can be used with other domains' registers. Whereas each register might have contents for each domain or each specific type, extracting cross-domain or cross-type contents from registers is not easy. In this paper, we present three register ontologies based on the ISO 19135 register schema model, the S-100 model, and the FCD model, respectively. As each register ontology represents concept classes and their relations on different level, we also present ontology-mapping methods for enhanced interoperability of GI registers based on ISO 19100 series.

Keywords: *Ontology, Ontology-Mapping, Geographic Information, IHO S-100, Maritime Data Model*

1. Introduction

S-100 is the International Hydrographic Organization (IHO) standard that recently was adopted as a basic model supporting the exchange and integration of hydrographic information services. To facilitate access to geographic information and its wide utilization, and also to support the development of S-100 based product specifications, the IHO maintains and publishes the Geographic Information (GI) registry [1].

The GI registry consists of several different register types. One type of IHO GI register is the Feature Concept Dictionary (FCD). It maintains and publishes definitions of geographic information in the application domain, which registered items are used to develop feature catalogues that describe data elements. Development of a feature catalogue for a specific application domain requires proper register items in FCD registers related to the application domain.

A register's contents are in dynamic flux: at any time, new proposed items are registered, and already-registered items are modified. Proposed items are accepted or rejected. Individual items are managed individually. Only valid items are made available to the public. The GI concepts represented in a register's items change over time due to changes in requirements or technology or other reasons[2]. With the IHO GI registry, ISO 19100 series-compliant registers interact. A register owner might choose to adopt another organization's item

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specified in a document or in a register, in which case the adopting register provides a reference to the source of the adopted item. An adopted definition can be changed only insofar as to accommodate differences in style between the source register and the adopting register, or to add contextual information. References can also be used to provide information on the historical development of a specification [1, 2].

As GI registers and their contents increase in number and amount respectively, interoperability among systems accessing, utilizing and managing those contents become crucial [18-21]. In this paper, we present register ontologies for representing and extracting semantic concepts and relationships pertaining to register contents. We present three register ontologies based on the ISO 19135 register schema model, the S-100 model, and the FCD model, respectively. In order to provide for compliance to the ISO 19135 register schema model and interoperability among the various registers, we present an ontology-mapping method for register ontologies based on profiles or extension of the three data models listed above.

The structure of this paper is as follows. In Section 2, the research on ontology mapping and register schema models in the maritime field is summarized. In Section 3, the register ontologies are introduced, and in Section 4, ontology-mapping issues and methods are discussed. In Section 5, conclusions are drawn and future work is anticipated.

2. Related Work

2.1. Ontology Mapping

Ontology is a formal, explicit specification of a shared conceptualization [3-5]. It provides a common vocabulary for the representation of a specific domain's concepts and relations. An ontology can be notated as a pair O = (S, A), where S is the signature describing the vocabulary and A is a set of axioms [6].

Ontology is used to extract information by means of a specific type of reasoning. A single ontology is no longer adequate for support of envisaged tasks within a distributed environment. It becomes necessary for multiple ontologies to be accessed from several applications. Multiple ontologies representing various levels of meaning and/or different domains can provide information on complicated tasks [6-11].

Ontology mapping maps the related vocabulary of two ontologies. Much research on ontology-mapping methods and tools such as ontological signature morphism, ontology alignment, ontology morphism, word translation and integration, and others, have been introduced. These can be classified into categories, such as frameworks, methods, translators, and mediators [6-11].

2.2. Register Schema Model

The IHO publishes and maintains several registers of unique, unambiguous and permanent identifiers that are assigned to geographic, hydrographic and metadata information items [1]. A register is simply a managed list that supports wider utilization of registered items. Existing register items can be clarified, superseded or retired, and new items can be added, as needed. Each register item has one or more associated dates indicating the times at which changes to its status occurred.

The register schema in the S-100 standard describes the structure of an IHO GI register [1]. The S-100 register schema is based on the register schema of the ISO 19135 standard. The register schema of the ISO 19135 standard uses UML notation to represent the components of a register, their related entities, and their associations in the form of a conceptual model. The schema consists of 13 classes representing the register information and nine data types used by the attributes of classes [2].

As the S-100 register schema model is profiled on the ISO 19135 standard, the structure of S-100 register is similar to that of an ISO 19135 register. However, some entities are restyled. Meaning of an entity differs from that of origin. For instance, the S100_RE_ReferenceSource and S100_RE_Reference classes are defined instead of RE_Reference and RE_RefernceSource, respectively. Their meanings are different from those of ISO 19135.

The FCD register is a type of IHO GI register. The FCD register schema is based on that of the S-100 register. A feature concept dictionary specifies a set of features, attributes, enumerated values and information types that may be used to describe geographic, hydrographic, and metadata information.

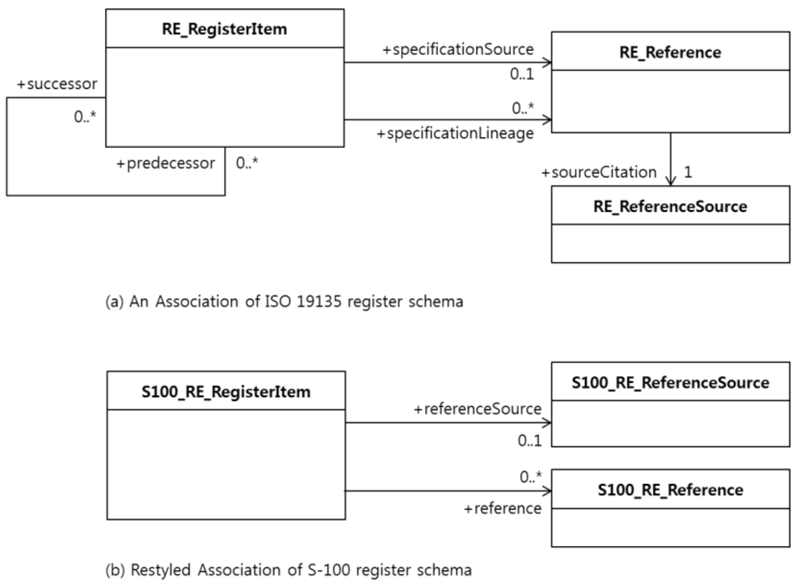

Figure 1. Example of Restyled Entity

3. Register Ontologies

In this section, we present three register ontologies for representation and extraction of semantic relationships among IHO GI register items and between register items and other elements. Using these, in the present study we built three register ontologies based on the ISO 19135 register schema, the S-100 schema, and the FCD schema, respectively.

3.1. Creation of Register Ontology

A register ontology is based on a register schema model that uses UML to represents concept classes and the associations among them. UML are converted to OWL [12,13]. UML classes of a register schema model are converted to concept classes in a register ontology. The attributes a UML class are converted to properties. A property's type is determined according to an attribute's datatype. For instance, 'name', of the characterString datatype, is converted to a datatype property, and 'citation', having an instance of the 'CI_Citation' object, is created as an object property with the range 'CI_Citation'. Additionally, an enumeration list is converted to a concept class and enumerated values are created as instances. The multiplicity of each attribute is represented by cardinality. The upper bound is set to max_cardinality, and lower bound to min_cardinality. The unlimited bound is set to 'someValue'.

Table 1. Converting Rules of UML to OWL

UML		OWL	
UML class		Concept class	
attribute	Datatype (ex. characterString, real)	Property	Datatype property
	UML		Object property
Enumeration		Concept class	
Enumerated value		instance	

Meanwhile, a metadata ontology imported into the register ontologies. In the register schema model, entities of the ISO 19115 metadata are used to describe the attributes of UML classes. Then, the metadata ontology, as built on the basis of 19115 metadata, is imported and used to represent the characteristics of concept classes [14-16].

3.2. ISO 19135 Register Ontology

The ISO 19135 register ontology is built on the basis of the ISO 19135 register schema that represents the register's elements and the relations among them that describe geographic information. Each element of the register schema represented using UML is annotated as an entity of the register ontology. The UML classes are defined as conceptual classes. Each attribute of a concept class is represented as a property.

This ontology import the metadata ontology based on the ISO 19115 metadata model, specifically the citation package. The citation package of the metadata ontology is used to describe the attributes of concept classes such as RE_Register, RE_RegisterItem, and RE_ReferenceSource.

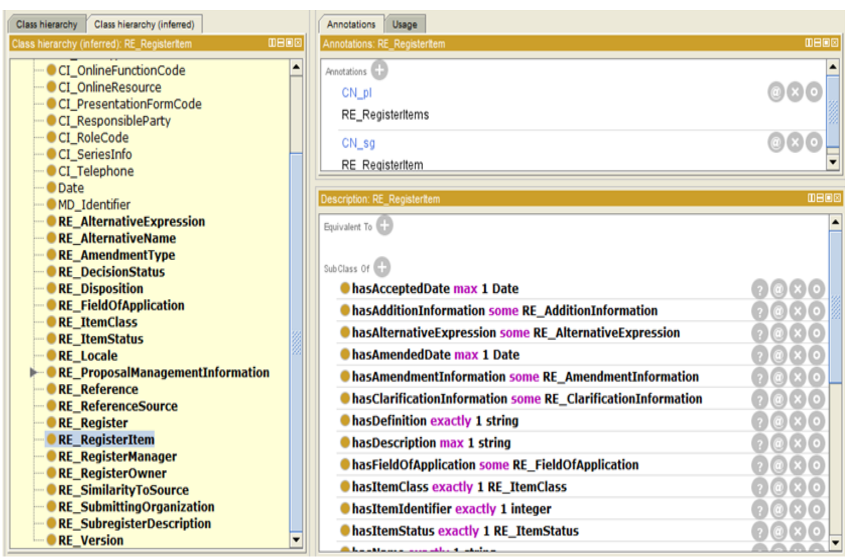

Figure 2. ISO 19135 Register Ontology Snapshot

3.3. S-100 Register Ontology

The S-100 register ontology is built on the basis of the register schema model in the s-100 standard. The S-100 register schema is a data model that represents the structure of the IHO GI register. As the S-100 register schema is a profile of the register schema model of the ISO 19135 standard, the ontology based on the S-100 register schema differ from the ISO 19135 register ontology.

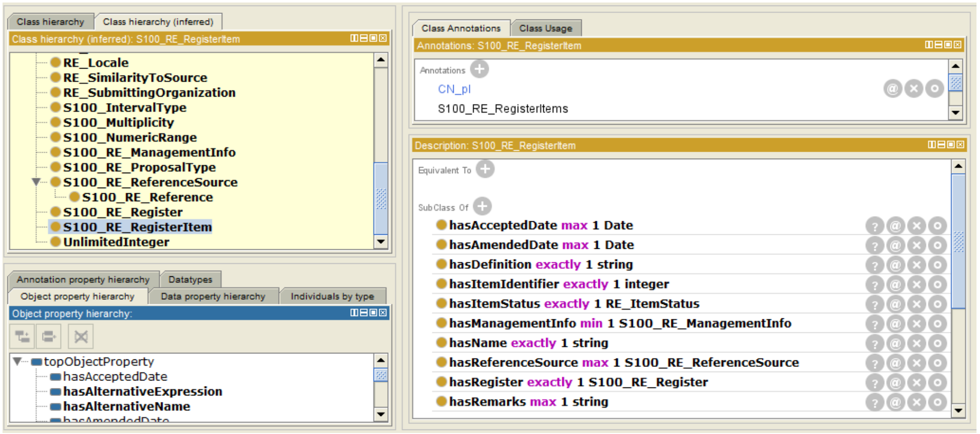

Figure 3. S-100 Register Ontology Snapshot

In the S-100 register ontology, some concept classes are redefined according to the meanings in the S-100 register schema model. For instance, S100_RE_Register and S100_RE_RegisterItem are redefinition of RE_Register and RE_RegisterItem, respectively, in the ISO 19135 register ontology. In these redefinitions, some of the attributes of the RE_Register are excluded and some new attributes are included.

3.4. FCD Register Ontology

The FCD register ontology is an extension of the S-100 register ontology. As an FCD register is a type of IHO GI register, the FCD register schema model is extended from the S-100 register schema model The S-100 register ontology is imported into the FCD register as an upper ontology. Therefore, the FCD register ontology includes all of the concept classes and properties of the S-100 register ontology. Additionally, some classes representing specific concepts, such as types of register items, in the FCD register schema model, are newly included. For example, the concept class S100_CD_RegisterItem is defined as a subclass of S100_RE_RegisterItem, which is imported from the S-100 register ontology. And S100_CD_FeatureConcept, S100_CD_InformationConcept, S100_CD_AttributeConcept, and S100_CD_EnumeratedValueConcept are defined as subclasses of S100_CD_RegisterItem.

4. Mapping of Register Ontologies

4.1. Relations among Register Ontologies

The register schema models dealt with in this research are closely related but different from each other. Among them, the ISO 19135 register schema model is the most general, representing the structure of the IHO GI register. The S-100 register schema model, in turn, is a profile of the ISO 19135 register schema model; likewise, the FCD register schema model is an extension of the S-100 register schema model.

The relations among the ontologies built on the basis of the register schema models are similar to those among the register schema models. The relation of the FCD register ontology to the S-100 register ontology is that of sub-ontology to upper ontology. However, the relation between the ontologies based on the S-100 register schema model and those based on the ISO 19135 register schema model is not clear. As the S-100 register schema model is a profile of the ISO 19135 register schema model, the meanings of some of the latter's concept classes are changed in, or excluded inform, former. For instance, the 'predecessor' and 'successor' associations in the ISO 19135 register schema model are not included in the S-100 register schema model; the concept class 'Reference' and 'ReferenceSource', meanwhile are redefined.

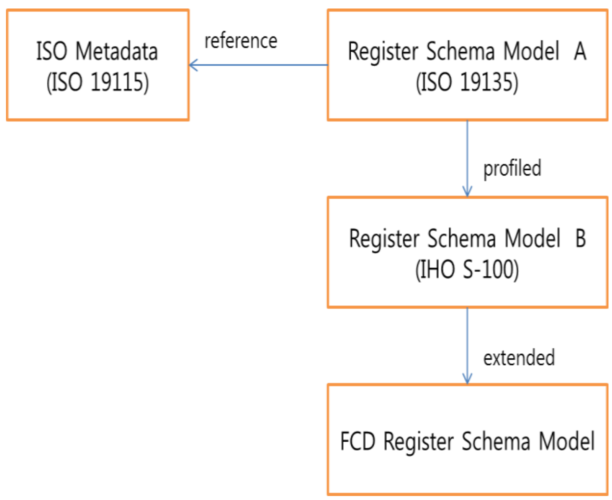

Figure 4. Relations among Register Schema Models

Even though the ISO 19135 register schema model is the most general and the S-100 register schema model references it, the ontologies based on these models cannot be set in the relation of upper otology to sub-ontology. When we notate an ontology as a set of vocabularies and axioms, each ontology is Oi = (Si, Ai), and the relations among the ontologies can be notated as follows;

$O_{FCD} \subset O_{S\text{-}100}$, $O_{S\text{-}100} \not\subset O_{ISO}$

$O_{ISO} = (S_{ISO}, A_{ISO})$: ontology based on ISO 19135 register schema model
$O_{S\text{-}100} = (S_{S\text{-}100}, A_{S\text{-}100})$: ontology based on S-100 register schema model
$O_{FCD} = (S_{FCD}, A_{FCD})$: ontology based on FCD register schema model.

4.2. Alignment of Ontology Entities

The FCD register schema model is an extension of the register schema model of the S-100 standard. For the purpose of representing the subtypes of a register item and their relations, some concept classes and associations are added to the FCD register schema model. As the FCD register ontology is a subset of that based on the S-100 register schema model, all of the vocabularies and axioms of the FCD register ontology can be semantically mapped to those of the S-100 register ontology. And as the S-100 register schema model is a profile of the register schema model of the ISO 19135 standard, the FCD ontology differs from that of the

ISO 19135 register. Even though many of the concept classes and properties of the S-100 register ontology are derived from the ISO 19135 register ontology, some of its concept classes and properties, though sharing the same names as those in the ISO 19135 register ontology, represent different meaning. Figure 4 provides an example of ontology-entity mapping.

In order to use these ontologies to support the integration of data and semantic search, we align the ontology entities with each other. Specifically, the concept classes and properties of the S-100 ontology are mapped to those of the ISO ontology. Some entities sharing the same meaning are set in the 'equivalent' relation; other entities are assigned according to similarity. 'Similarity' between ontology entities refers to 'RE_Similarity'. In this paper, we define properties to set the relation among mapped concept classes. The properties are symmetry and transitive.

Concept	Register Schema Model A	Register Schema Model B	Register Schema Model C
ReferenceSource	itemIdentifierAtSource [0..1] similarity referenceText [0..1] notes [0..1] sourceCitation	referenceIdentifier [0..1] sourceDocument similarity	same as the S-100
Reference	citation	referenceIdentifier [0..1] sourceDocument	same as the S-100
RegisterItem	itemIdentifier name definition description [0..1] status dateAccepted [0..1] dateAmended [0..1] fieldOfApplication [0..1] alternativeExpression [0..1]	itemIdentifier name definition remarks [0..1] itemStatus dateAccepted [0..1] dateAmended [0..1]	same as the S-100, included a subclass 'S100_CD_RegisterItem' of the S100_RE_RegisterItem

Figure 5. Example of Ontology Entity Mapping

5. Conclusions

A register schema model indicates the structure of a register. IHO GI registers are used to facilitate the wider used of, the ease of access to, and the development of S-100-based product specifications, and for other purposes as well. When registers for specific purposes are widely used, issues such as semantic searching and data integrations become important. Especially in the maritime field, the integration of ship-to-ship, ship-to-shore information services and the relevant platforms is a key issue.

In this paper, we introduced three ontologies based respectively on three register schema models in order to support semantic searching and the integration of data with various domain registers. We uncovered the relations among the register schema models and developed an ontology for each in order to enable easy interoperability with the other registers. Also, we developed, and explain a mapping method of register ontology. We focused especially on mapping ontologies based on a general data model and its profiled data model. With register ontologies that can be mapped to ontology based on a general data model, semantic integration and searching are facilitated. These ontologies with the ontology mapping method, significantly, can support the wide utilization of IHO GI register contents and ISO 19100 series-compliant register contents. And, these ontologies can support cross-domain and/or cross-type searching semantically related contents.

In future works, we will apply these ontologies to the development of feature catalogues and the extraction of information on the basis of the relations among feature and feature catalogues or feature and others. Additionally, we will study the extraction of semantically related features in various domain registers using these ontologies.

Acknowledgements

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